JOURNAL OF THE
BOSTON SOCIETY
OF
CIVIL ENGINEERS

FEBRUARY - MARCH - 1933

VOLUME XX NUMBERS 2, 3

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JOURNAL OF THE

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OF GENERAL INTEREST

Proceedings of the Society 48

Published Monthly, except July and August, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price, $4.00 a Year (10 Copies)
50 Cents a Copy

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Entered as second-class matter, January 15, 1914, at the Post Office at Boston, Mass., under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

The Society is not responsible for any statement made or opinion expressed in its publications.

Boston
Wright & Potter Printing Company
32 Derne Street

JOURNAL OF THE
BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XX FEBRUARY–MARCH, 1933 Numbers 2, 3

BOND IN MASONRY CONSTRUCTION

WALTER C. VOSS,* MEMBER

(Presented at a meeting of the Boston Society of Civil Engineers, April 20, 1932)

MEMBERS OF THE BOSTON SOCIETY OF CIVIL ENGINEERS AND FRIENDS: The subject which your Program Committee has assigned to me for discussion this evening, although much spoken of these days, is one which causes any investigator to hesitate in drawing conclusions. It seems surprising that one of the oldest arts in history should create such a sudden burst of interest. It is more surprising that so little is known, definitely, about the behavior of masonry units and mortars. I can assure you that it is a problem that grows large in its scope as one probes into its details. A veritable labyrinth of uninvestigated channels stares one in the face. Who knows what is beyond?

A peculiar complex has grown up during the past decade of unprecedented activity in building and research. The free lance in almost every field has often gone far astray from the original problem. Commercial exploitation of every possible material and scheme has added tremendously to our difficulties. The engineer has worshipped strength; the architect has knelt at the feet of beauty; the contractor and the owner have paid tribute to the dollar; the manufacturer has busied himself with trade propaganda and has played up to the caprice of each; and last, but not least, labor has run wild in its control of production.

I believe you will agree with me that all of us have been guilty of one or more of these narrowed views. We have all lost sight of the problem in hand, together with its most simple commanding solution. This problem may be simply stated as "The production of a beautiful weather cover of masonry units and mortar that will serve to keep out the elements." The problem has never been more complex than this statement indicates. Its apparent complexity has arisen from a multitude of activities on every one's part, most of which were motivated by selfish desire, if I may class it as such.

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This problem involves four major criteria or agencies. These are the materials, the design, the human element and the weather. The first of these, the materials, are so great in number and character as to actually stifle the imagination. Even in masonry materials, we probably have more kinds than perhaps we need, and surely more than years of research may completely analyze. In design we have the engineer and the architect guilty more times than one can tell of details coupled with certain materials that are strictly incompatible, and which, perhaps, even a little sober thought would drop from consideration. The human element, perhaps the most important single item in the solution of any of our problems, is one which is as often depraved as it is laudatory. Selfish desires have motivated most of our building programs for many years. Each element in this giant of industry has contributed liberally to barriers in the path of progress in many of our problems. The weather is quite as important in a building program and its well-rounded study as it is to an army. To send fur-clad troops to the equator for a conquest is equally as ridiculous as building a summer house at the north pole.

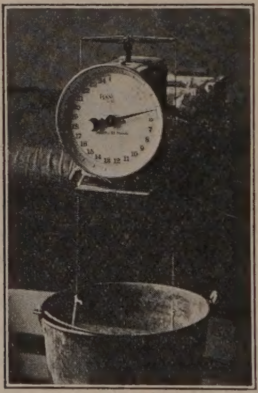


Fig. 1.— Postal Scale Rig

In all of this preachment, which seems destructive criticism, may I ask you to bear with me until I attempt, at least, to lay a background which is firmly bonded to each of your experiences in these matters, so that when the "old wolf comes to you in sheep's clothing," regardless of what kind of wolf he may be, you will be prepared to ask him a few simple questions regarding his conclusions, propaganda or material. May I therefore elaborate on the last three criteria, reserving materials for a little more detailed discussion.

The design, then, of a building bears an important relation to its success as a weather cover, more particularly for masonry walls. As an engineer, you may specify, having your ever-present strength complex uppermost in your mind, a masonry unit of a certain compressive strength in pounds per square inch, and you will recommend that this unit be laid in a mortar with an equally high compressive strength. What thought have you given the matter of homogeneity? None, perhaps, except in rare instances. If you have, what have you done about it? As an architect, you have selected a unit of a certain color, a definite texture to please the eye and to express unity in your design; you have made your mortar joint likewise, and have tampered with it as a modeller does with clay. All of this to please your eyes and your preconceived notions of good design. You have selected a unit which is absolutely watertight, and, what is more, you have laid it in a mortar that repels moisture like a "duck's back." Surely this should be sufficient. Both the engineer and the architect have adopted new materials, new economic structural frames, new schemes for city structures, and you both have written, or caused to be written, building codes which embody such schemes, to meet present-day metropolitan needs without a single thought, definitely directed toward compatibility of scheme and material. In short, we have all been guilty of assembling

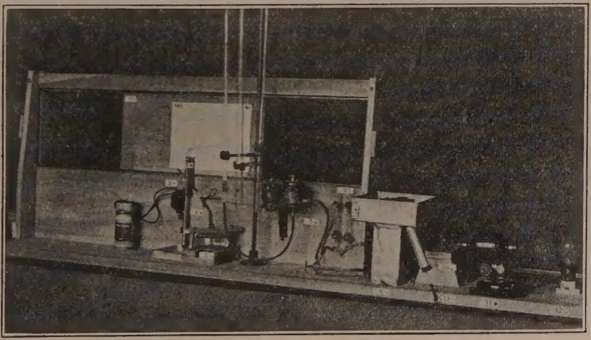


FIG. 2. — FIRST ABSORPTOMETER

materials in such a way as, in many instances, precluded failure as weather covers.

The human element in this entire picture is one upon which I could and would like to dwell at great length. Time forbids this, but I will barely outline some of the most important features. Perhaps some of you immediately think of labor. True enough, this is a part. But, more important, to my mind, at least, is that portion of the human element which centers around sales, friendship and kinship, politics and cost. We may just as well as not talk frankly on these matters. The facts are known to all. A company which has a product to sell is in business for profit. Vast sums of money are invested in its plant and equipment. Just because it makes a product which is inferior for certain uses must not curtail sales for that very purpose, if it will be reasonably successful at all. A great deal of research has been conducted toward the end that sales points were wanted.

Many of these researches were specifically conducted to discover even the most unimportant advantages. These have been "trumped up" in advertising, beautifully and plausibly presented, and you and I have "swallowed" many times. On some occasions these researches have uncovered characteristics distinctly unfavorable to a product. These have been carefully filed away. Such information might destroy all the advantages gained and jeopardize the success of a large investment. Compare this with your attitude toward one of your employees, such as a structural engineer. I do not believe the engineering profession is gullible, but I do believe it is so completely steeped in calculations and calculus that it cannot see the forest for the trees. I advise an investigative point of view. Let us all "be from Missouri" for awhile. Put your engineering judgment at work on materials and methods as well as on strength, indeterminate structures and the other admirable subject matter so generously contributed thus far to the industry.

Friends and relatives are in business making a material or device. They plead for a chance to enter the field of your design. You weaken, and often, rather than possibly hurt your friends, directly injure a client and your own reputation. What a field for speculation, for error and for trouble the words "or equal" present. It is perfectly fair to write these words, providing you are able, willing and authorized to exercise discretion. Many good intentions on the part of architects and engineers have been wrecked on the rocks of these two little words; and far too often the owner has had a very definite responsibility for the wreck. Politically, this matter of substitution, favoritism and whatever else may enter is doubly deplorable. For fear of "graft" we legislate against the definite specifications of a good product, and accept in exchange an inferior substitute because some one else says "use this." How ripe the harvest of misdirected endeavor is along these lines. Lastly, may I consider the human element involved in labor. As long as our present system of labor union control exists, so long will we have to content ourselves with certain tradesmen on every job who had better never have learned the trade. A union card entitles the indifferent, careless and unskilled tradesman to all of the privileges that the skilled mechanic enjoys. The larger proportion of the trades are skilled, to be sure. It is the "hangers on" who put that point in the wall that grievously causes trouble. These men are not interested in craftsmanship. To discharge them unceremoniously would be to court trouble. Jurisdictional arrangements often make it impossible to so construct certain elements of an exterior wall that it may be watertight. It is not the wall these men are interested in; they are selfishly seeking an advantage which will keep them most continuously and gainfully employed.

All of these elements conspire to defeat good construction. They must all be controlled and eliminated if uncontrollable. How this may be done is the problem of the sociologist and economist; perhaps of religion. You, as engineers and architects, must not only resist the inroads of such evils, but you should have the courage to fight them openly.

With this rather generous introduction may I come to the main portion of this discourse. I hope you will allow me the privilege of invoking discussion by making some statements which are at present opinions and which may be subject to revision as additional study may dictate. I have no final conclusions to offer you; I doubt if any one should at this moment. I shall divide my consideration of these matters under four general heads, namely, (*a*) brick, (*b*) mortars, (*c*) structural tile and (*d*) stone.

Brick, particularly clay brick, have had a tremendous amount of publicity of late. Besides the clay brick we have the sand-lime brick and the concrete brick. We have been led to believe that all brick were approximately the same. I may confess that, outside of the sand-lime, concrete and vitrified varieties, I, too, was of the opinion, not so long ago, that our troubles surely were not resident in the brick. I have found that clay brick, discussing these first, are quite variable in their behavior. Great differences exist, even in a single delivery from a single kiln, in some types.

In our study of this product we started out with the assumption that density might have some relation to some of the other characteristics of a given variety of brick. Our first step was to check up a delivery of common brick, actually measuring and weighing some 2,500 separate brick. We determined for each brick its specific mass gravity, or $\frac{W}{V}$ in ounces per cubic inch. This value we have named density coefficient, for want of a better name. These brick were then sorted into piles whose variation in density coefficient was not greater than .05 ounce from the highest to the lowest. A selected set of specimens, all with the same coefficient, were then tested for absorption at 1, 2, 3, 4, 5, 10, 15, 30 and 45 minutes, and 1, 2, 5, 12, 24 and 48 hours. These values were plotted and showed remarkable coincidences. (I shall discuss this and later tests with slides at the close of my paper.) The brick were then dried to constant weight and tested for modulus of rupture and in compression. These, too, showed remarkable adherence to our preliminary assumptions, with the exception of the modulus of rupture, which decreased with increases in the coefficient in the higher ranges. This probably is due to a brittle structure caused by partial vitrification.

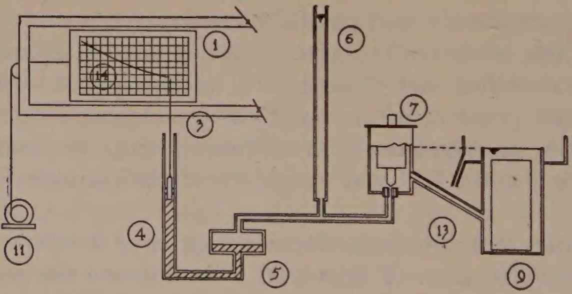


Fig. 3. — Diagram of First Absorptometer

The most amazing element to me in these tests was the fact that for the varieties tested, mostly all of the brick took more than 50 per cent of their total forty-eight hour absorbed water in less than ten to fifteen minutes. These tests indicate rather clearly, at least for the present, that a brick which is manufactured in such a manner as to produce capillary pores of small diameter will rapidly absorb its complement of water, and if wet will have practically all capillary suction destroyed. Later bond tests indicate that the presence of a given amount of capillary suction is absolutely necessary to a good bond.

Vitrification and extreme density, although increasing strength and individual weather resistance as far as the brick is concerned, are destructive to bond between the brick and the mortar. Further tests on "bone dry" specimens and drenched specimens have clearly illustrated this fact for any given variety, all other factors being held constant. Again, a brick which may absorb great amounts of water in the early minutes when combined with a mortar which should not lose water will definitely set up destructive bond factors. Likewise, such a brick when combined with a mortar that can lose water without losing strength will assist in the bond.

The actual development of a chemical bond is still uncertain. If a chemical bond is developed, it will certainly depend upon the materials in contact. It is quite fair to assume that certain materials in contact will produce no or very little chemical bond. Even though the materials are known, which they are not in some instances, there are physical characteristics which greatly influence the bond. This has been, tentatively at least, proven by tests which show that a more porous brick from the same kiln produces a better bond with a given mortar than one which is more dense, providing, always, that the pores are capillary tubes, and that other elements, such as excessive suction, do not influence the final result.

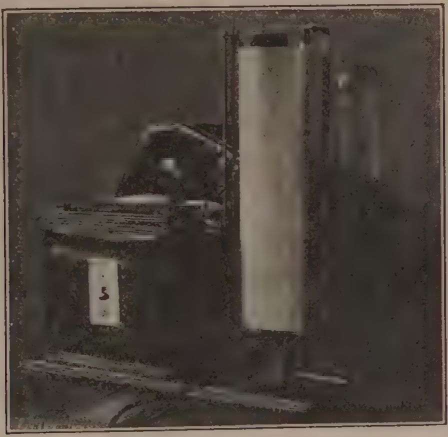


Fig. 4. — Second Absorptometer

The physical characteristics of the brick certainly have an important bearing upon bond. The capillary suction of the structure of the brick draws tentacles of the cementitious material toward the brick surface, and if the particles of this material are small enough to slightly enter these pores, and of a sufficiently tenacious character, a fine physical bond will probably be produced. If, in addition, the porous structure and constituents of the units have the same or nearly equal coefficients of expansion and contraction, this bond will not be disturbed to a great extent. If, however, the movement is material in proportion to the shear and bending strength of the bond producing elements, rupture will inevitably result. If the brick is laid absolutely dry, this suction will be great. If, however, it does not continue over a small interval and at a reasonably slow rate it causes the mortar matrix to congeal, and thereby defeats the impenetration.

It seems, then, that a brick should have a relatively high suction rather than an extremely low one; this is almost diametrically opposed to the tendency of modern thought on the subject for quite a number of years. It follows, also, that this suction should be produced at as slow a rate as is consistent with the ability of the mortar to remain plastic.

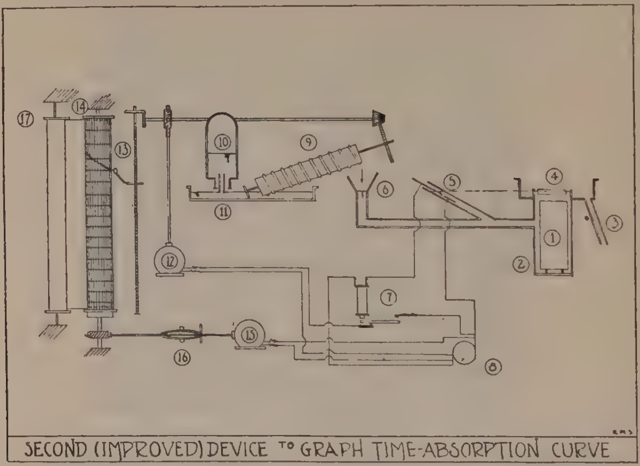


Fig. 5. — Diagram of Second Absorptometer

All of these matters have been discussed thus far from the standpoint of the ideal conditions of an investigation. They must all be tempered with the practical judgment of the field. They must take into consideration the effect of climatic changes, such as freezing and thawing. They must be so simplified as to make them ready and easy of accomplishment in the field. Perhaps the most important field consideration, and perhaps the one most difficult of exact accomplishment, is that of tempering the suction of the brick to produce the desired speed and amount. This heretofore has been attempted, and partially provided, by wetting the brick down in the pile, a most unsatisfactory practice. In the winter this method cannot be followed, and disastrous results follow where the same brick and mortar are used throughout both seasons. The ideal brick, therefore, is one which may be laid bone dry.

To pass to a similar discussion of mortars at this point would be advisable, leaving some of the other points of interest until later. The cementitious materials commonly in use today are lime, Portland cement, natural cement and hydraulic lime. You are probably familiar with them as cement mortars, cement lime mortars and prepared masonry cements. May I say right here that the character of the sand is very important, a very fine sand producing unusually high shrinkage values and contributing to failure in bond by differential shrinkage between brick and mortar. To be sure, a study of sand is quite important and is not being overlooked in our tests. I would like, however, to discuss the cementing materials themselves from such small experience as I have had with them.

Limes vary just as cements vary. The two major divisions from a chemical point of view being the high-calcium, so-called high-yield, limes, and the dolomitic, or magnesian, limes, which are quite different. To talk with the average eastern lime man is to hear a eulogy on high-calcium limes. To listen to a mid-western lime merchant one would think that dolomitic limes are the only kind worth considering. Nevertheless, both are in the field. Both have been used with success and failure, apparently. At present our knowledge from test data, uncolored by prejudicial thought, is very meager. I hope we will know much more about them in the not too distant future. This much, however, we are reasonably sure of: slaking action proceeds much more rapidly with high-calcium limes. This may result in burning if slaking is carelessly conducted. The magnesian limes either do not slake completely, or, if they do, long curing periods may be necessary to produce a mortar free from movement in the wall. It is my present opinion that very little of the magnesium oxide slakes, and remains free to combine with something or another later. We may have to retract this statement in the light of future tests, but for the present it is our best opinion. There are precautions which must be observed in using either, and these are care in slaking, proper aging and the advocacy of slaked lime putty for mortars instead of hydrated lime. Most contractors will agree that the mortars resulting from the use of lime putty are much more plastic and easy to work; or, as the mason says, "fat."

Portland cements are worthy of some comment, also, when considered as mortar constituents. Brand should be selected for plasticity and ready hydration when used for mortars. High early strength cements should be avoided. A more slowly setting cement may, indeed, be more efficacious. We must remember, however, that one of the outstanding features of Portland cement is its "setting," not its hardening, as a lime mortar. It is a material which "congeals," so to speak. It does so quite rapidly when in contact with a "high suction" surface. Another important fact about this material is the necessity for "curing," or proper amounts of water to "feed" the setting action so it may proceed unchecked. With all this, Portland cement mortars are similar to other mortars in that they consolidate under load, though not as much as lime mortars do. No one, as far as I know, has taken the continuous shrink and swell out of Portland cement products, except those produced under pressure (where a small amount is still evident). If this continual movement is quite large, differentially, compared with the masonry unit, the bond will ultimately be broken. It is quite possible that clay units exist which under ordinary conditions may be ideal for cement mortar, but as yet I have not discovered them. My research, however, has not extended over any very large range of such units to date.

Portland cement, or some form of "setting" cement, has an important place in masonry work, as far as I can see. Practically, a mortar must harden sufficiently to allow progress on the job without causing weaving in the wall. Straight lime mortars do not provide such a material, and some cement must be used. How far to go is an open question. I have tested lime and cement combinations all the way from 1 part of cement to 3 of sand, with the proverbial 10 per cent of lime, to 1 part of cement, 3 of lime, and 12 of sand. As far as my tests may be an indication in this direction, I at present stand upon a proportion of 1 part of cement, 1 part of lime putty to 6 parts of sand. This combination has given me the best results with most of the bricks tested, has a very satisfactory compressive strength and modulus of rupture, and has withstood the freezing and thawing tests quite well, considering all its other good qualities. Perhaps the most important characteristics which a mortar should possess, outside of its adherence to the brick, is the property of self-healing should breaks occur in the mortar itself. A good lime increases its ruptural resistance by alternations of wetness and dryness. It does not carbonize as rapidly as we have been led to suppose, but remains for the most part in the form of hydroxide crystals which may become active again upon occasion.

The load to which a brick wall assemblage is subjected plays an important part in the bond strength developed. Light loads such as those imposed by parapets and spandrels are not sufficient to effect any great change. Heavy loads, however, do increase the bond strength developed, probably because they assist in consolidation and adjustment, thereby creating more intimate mass contact. The tests which we have made along these lines have not been completed, as the one-year specimens are to be tested next September. Twenty-eight day tests based upon laboratory conditions may lead to serious error in conclusions, and we are using them only to determine the behavior of various factors, and to control all others as far as possible. The exposed wall tests made to date in various sections of the country are not safe for the drawing of final conclusions, in my opinion.

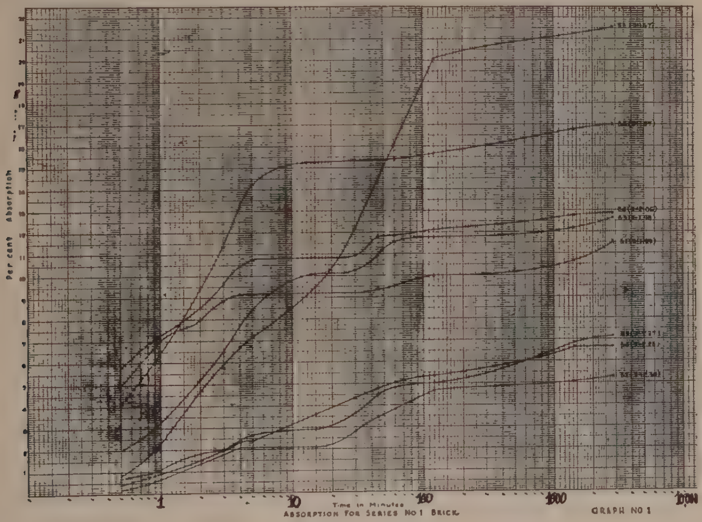


FIG. 6. — PLOTTED ABSORPTION CURVES

Prepared masonry mortars have been used for a great many years, and seem to have had the same troubles that all others have experienced. The use of "some one's misfortune as a feed for one's breakfast" has been altogether too prevalent. Manufacturers have reveled far too often in the failures of their competitors, having a complete schedule of their own "skeletons" of failure to look back upon. The outstanding prepared mortars when produced under the control prevalent in the best factories have as much of a leg to stand upon as the job-mixed varieties of combinations of lime and cement. There are undoubtedly prepared mortars on the market that might well look to their laurels in this matter, and there are probably some we have not encountered which are excellent. This we propose to find out some time not too far away.

I do not wish to pass over sand-lime and cement brick. I frankly have not investigated either of these varieties in this present series of tests. They will, however, be tested similarly. I am perfectly sure of this, however. A cement mortar used with concrete brick will produce an excellent bond, better than any bond it could possibly produce with clay or sand-lime products. The trouble is that the bond is too good. A monolithic concrete wall without reinforcement, large in extent, is produced, and cracking results when expansion and contraction take place. Cement products weave when in the presence of moisture and subsequent dryness, and this must be provided for by suitable design. Sand-lime brick are supposed to be composed of calcium carbonate. This I doubt very much. They certainly absorb a generous amount of water, but this need not be detrimental from a bond point of view. It is responsible, I believe, however, for the failure of many sand-lime brick to resist frost action. I hesitate to give merely opinions. May I request that I be allowed to let these materials rest upon their present status until we know more about them.

I will hastily pass over structural tile, both clay and concrete, taking the position that they should be used only as back-up units, and when used exposed, that they be treated as clay products subject to as serious discrimination as brick.

Stone, both natural and synthetic, has been used with great success, as far as weather-tightness is concerned. Needless, perhaps, to say that I prefer natural stone to cast stone, as it is less subject to weaving in the wall. Cast stone, even some of the best varieties, has given quite a great deal of trouble from many points of view. This great industry is, however, studying its limitations carefully, and will undoubtedly report some progress in the near future. I believe, however, that the secret of such success as we have had with stonework rests upon two usual practices. It is usually parged and it is almost invariably pointed. It possesses great weight in each unit and is usually incorporated into walls of some appreciable thickness. Then, again, it is usually more carefully and expertly set.

Let me summarize, then, some of the more general matters which have to do with successful or unsuccessful masonry work. When I make these recommendations, please accept them as my current opinion on this matter, and remember that I have not by any means exhausted the avenues of investigation. I would use a relatively absorbent brick, with an absorption around 10 per cent, and I would lay this brick in a mortar composed of 1 part of cement, 1 part of lime putty and 6 parts of sand, all by volume. I would keep my joints between one-fourth of an inch and three-eighths of an inch, never larger, and I would parge the face brick before backing up. I would advise bearing wall work where possible, and where inadvisable I would thicken up all walls to 12 inches. All exterior joints should be ruled as work proceeds from lead to lead or lift to lift, ironing retempered mortar, where necessary, into all joints. I would abolish trowel-cut or trowel-weathered joints. Where possible, I would use natural stones of sizable proportions and set them just as for the brickwork just described. Where an integral waterproofer is used with the mortar I would assure myself that it is one which does not defeat capillary suction, but that it should aid it by reducing the surface tension of the water in the mortar. I would indulge, particularly for very important work, in some investigation of the unit and its proper mortar complement before blindly specifying, by the use of generalities.

You will accuse me, or perhaps you already have, of indulging in glittering generalities myself, thus far. I would like now to give you some of my results which tend to illustrate the why of my present opinions. I will make these comparisons, and perhaps comparisons will be more enlightening than tabulated figures, in about the following order:

(*a*) Relation of specific mass gravity to absorption, compressive strength and modulus of rupture.

(*b*) Effect of freezing and thawing on several varieties of brick.

(*c*) Effect of freezing and thawing on several varieties of mortar.

(*d*) Comparison of shear and tensile bond for varieties of brick, mortars, load and degrees of pre-wetting.

(*e*) Comparisons of rate of absorption for various brick types.

(*f*) Microscopic studies.

The only brick types we have tested thus far are a grade of dry-pressed, shale-face brick; a shale, wet-mud, pressed-face brick; sand-struck common; and water-struck common. These we will designate as T–1, T–3, T–4 and T–6, respectively. Each of these varieties has been kept constant as far as possible by deliveries from the same manufacturer. It is our hope to continue the basic study of clays, as we feel that all materials now classed as clay do not produce the same final characteristics, even if similarly prepared and uniformly burned. Our data are therefore too limited for final conclusions, and any one who draws a final conclusion on so limited a group of tests would certainly run into trouble. Nevertheless, these results are measures, at least, of the tendency.

Translating the tests on absorption and strength to curves for comparison, it was noted that total absorption was reduced by increases in the specific mass density; that the compressive strength increased with this coefficient; and that the modulus of rupture also increased, but showed a decline or flattening out in the higher ranges. Nevertheless, the tendency is very clearly indicated. Keep in mind, however, the fact that these curves which indicate total forty-eight hour absorption are not indicative of rate.

The effects of freezing and thawing on both the brick and the mortar is also interesting. The number of tests still in the laboratory, and which may disclose very important data, or even reverse present data, is sufficient argument for the omission of many of the details at this time. A few present indications will be worth while. The freezing process involved an average exposure to —10° C. for about three hours. Thawing was accomplished by complete immersion in water at about 80° C. Ten cycles were used and the specimens were then tested.

The mortars which I will compare this evening are the two now so conspicuously loved and despised, and *vice versa*, namely, the 1 cement, 3 sand with 10 per cent of lime hydrate, and the 1 cement, 1 lime putty and 6 sand. I will refer to the former as M–2 and the latter as M–4 for convenience. This study is based upon twenty-eight day test data.

I am not drawing any conclusions from these data, as I do not believe I should until a great many more corroborative tests have been made. They do show, I believe, that the 1–3–10 per cent cement mortar enjoyed freezing considerably more than the 1–1–6. They also show considerable loss in strength when using a 1–1–6, but it must be remembered that the cement mortar specimens nearly all broke at the juncture of the brick and mortar, while most of the lime mortar specimens broke with high percentages in the mortar itself. This indicates, perhaps, that under the vigorous conditions imposed a 1–1–6 may be too rich in lime. I do not believe the discrepancy after a year's exposure will be as great. Twenty-eight day tests are very misleading when comparing a mortar high in cement and unyielding in its nature with one which requires time to harden, and which is flexible and possesses healing qualities, particularly if the break should come in the mortar and not the bond plane.

Permit me still to take the time to finally discuss our hypothesis on the conditions which exist at the bond plane as affected by the suction of the brick and its pore size.

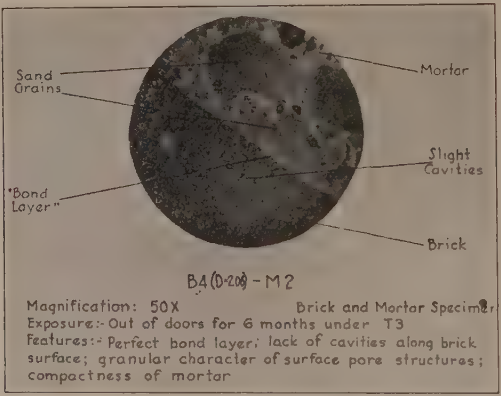
It is rather essential that some foundation be laid to which results of experiments and researches may be related, and in this matter the research conducted on brick and mortar bond might perhaps be better co-ordinated if an hypothesis was worked up from the facts now known. For the basis of this hypothesis the study of brick, and brick and mortar samples under the microscopic lens, has been leaned on essentially, with a little knowledge of the results obtained from mechanical and other tests.

With the proper type of brick and mortar, and with the proper conditions, a good tight bond, which will hold to the brick under all weather conditions and exposures with no leakage of water, will be the result primarily of the passage of water from mortar to brick during the set-up of the brickwork. This passage of water, due to the sucking action of the minute pores of the brick, will pull along with it fine particles of cement or lime. These particles, although fine enough to permit their passage through the interstices of the mortar, are not small enough to pass into the fine, minute pores of the brick, and as a result a layer of cement will be built up next to the brick and extending back into the mortar. The passage of water still continuing through the particles, a wedging action will further tighten the contact of these particles to the brick, and, together with the absorption of water by the particles themselves which cause them to swell and then crystallize, further increases the pressure of the cementing layer against the brick surface. The passage of water may then be stopped by a lack of water in the mortar, by an entire filling up of the pores in the brick, or, more probably, by the layer itself, which has so swollen and tightened as to make an impervious layer. The layer will then harden like any cement, and will shrink, *but* if the contact with the brick has not been destroyed, the brick will act as would reinforcement, and will prevent the layer opening up any large cracks, but only minute ones, which will not allow any great passage of water through the brickwork.

It is essential to remember that there are many variable factors influencing this whole procedure. The brick itself has considerable effect, since its nature will dictate the manner and speed of the water passage from mortar to brick. The pores in the brick must be large enough to give sufficient suction, but small enough to prevent entrance of cement particles. Large holes adjacent to the surface will either cause air pockets, which will prevent a tight contact on the surface adjacent, or will cause an entrance of cement particles at these points, which will decrease the amount available in that vicinity as well as destroy the even wedging effect necessary for tight bond.

The rate of water passage will be dictated to a large extent by the amount of water present in the brick when laid up. If it is dry, the water flow will be so rapid as to not give sufficient time for the cement particles to get moving from the mortar interior, and while a very thin layer will be built up by those cement particles found in the mortar in those narrow layers adjacent to the brick, the wedging and swelling will not be as strong, and the bond will be poor. If the brick is 100 per cent water soaked, no passage of water will result, and therefore no bond. It is necessary, then, that the brick be wet, but not soaked; and the amount of water can well be ascertained by an examination of the curve of absorption obtained from the "absorptometer."

Turning to a visual proof of these statements, an examination of a red water-struck common showed a brick with many minute pores and occasional large holes. This brick is an average type, its pores as minute and regular in occurrence as any, and quite in accordance with the properties essential for a good bond. Fig. 7 shows this brick with a 10 per cent lime hydrate mortar, showing the tight contact of mortar with brick, no cracks showing, and no holes in the mortar to indicate a weak spot or shrinkage crack.

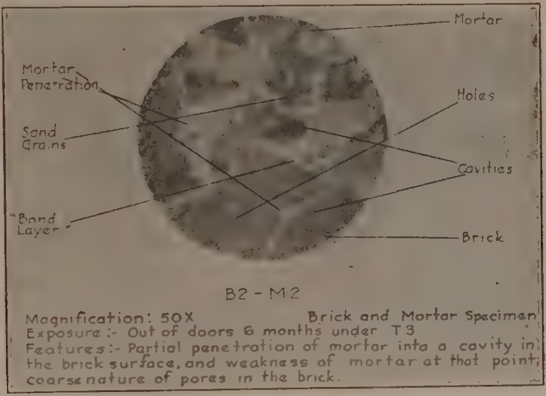


B4(D-206) - M2

Magnification: 50X Brick and Mortar Specimen
Exposure:- Out of doors for 6 months under T3
Features:- Perfect bond layer; lack of cavities along brick surface; granular character of surface pore structures; compactness of mortar

FIG. 7

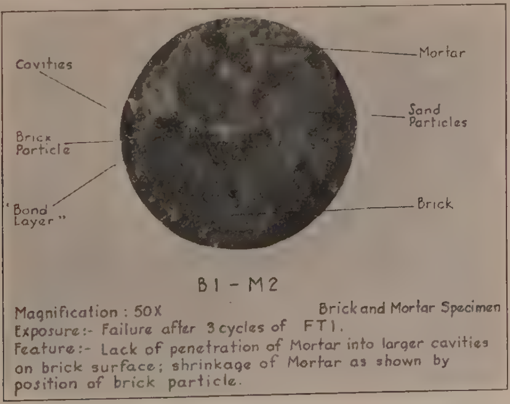
Fig. 8 shows a red mud face brick with a 10 per cent lime hydrate mortar, whose pores are larger than the water-struck common, and which has breaks and holes next the surface, allowing mortar penetration. If it were not for the latter the brick would be perfect for a bond, since it is a well burned brick, as is shown by the round character of the pores, round pores being better than the angular ones found in the previous brick type. But the cement particles can enter the brick, and are drawn away from the surface, as is shown by the holes and cavities in the mortar. Fig. 9 shows the effect of freezing and thawing on a dry-press face brick, this specimen being subjected to three freezings to — 12 C., and soaking in hot water afterwards. The close contact of mortar to brick is seen in the middle, while the lack of mortar adjacent to the larger hole in the brick is likely, due to a mortar penetration farther down the surface. An interesting point to note is the shrinkage of the mortar, which has taken with it a particle of the brick (center, below the large particle of sand).



B2 - M2

Magnification: 50X Brick and Mortar Specimen
Exposure :- Out of doors 6 months under T3
Features :- Partial penetration of mortar into a cavity in the brick surface, and weakness of mortar at that point; coarse nature of pores in the brick.

FIG. 8



B1 - M2

Magnification : 50X Brick and Mortar Specimen
Exposure :- Failure after 3 cycles of FT1.
Feature :- Lack of penetration of Mortar into larger cavities on brick surface; shrinkage of Mortar as shown by position of brick particle.

FIG. 9

In Fig. 10 is shown a red sand-struck common with 10 per cent lime hydrate, where apparently the hypothesis is refuted, since the holes in the mortar have no obvious explanation, except that possibly the brick was 100 per cent wet or nearly so (as might often be found on the lower side of the brick in the laying, which brick has not had sufficient time for an evaporation of excess water). But even here the mortar has made tight contact with the brick. Another explanation for the holes was that the brick was laid up dry, and the passage of water from mortar to brick was so fast that it did not allow a building up of cement particles, as was shown in the other pictures.

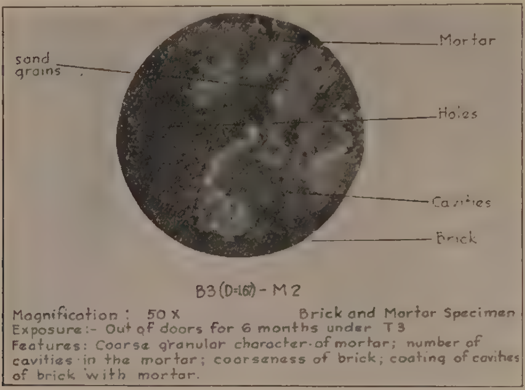

sand grains
Mortar
Holes
Cavities
Brick
B3 (D=167) - M 2
Magnification : 50 X
Brick and Mortar Specimen
Exposure :- Out of doors for 6 months under T3
Features: Coarse granular character of mortar; number of cavities in the mortar; coarseness of brick; coating of cavities of brick with mortar.

FIG. 10

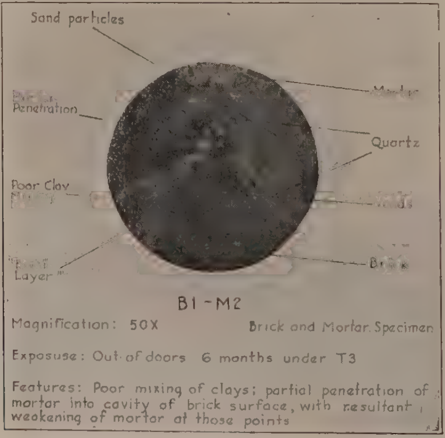

Sand particles
Mortar
Penetration
Quartz
Poor Clay
Layer
Brick
B1 - M2
Magnification: 50X
Brick and Mortar Specimen
Exposuse: Out of doors 6 months under T3
Features: Poor mixing of clays; partial penetration of mortar into cavity of brick surface, with resultant weakening of mortar at those points

FIG. 11

The red dry-pressed shale brick, a rather unusual brick because of the large irregular cavities found throughout the brick, and whose remaining pores would be sufficient for obtaining a good bond, since they are quite minute enough, is shown in Fig. 11, with 10 per cent lime hydrate mortar, giving a close contact along one portion with a penetration and resulting hole in the mortar. This particular specimen must have been laid up with the proper condition of wetness, as is shown by density of the mortar, showing a long building up of cement particles, with no sudden or uneven penetrations which would disturb the evenness of the wedging and swelling action in the mortar.

The factor of large holes in the brick is one which will dictate the length of time necessary to allow the brick to stand after wetting. These holes allow the water to flow fast through the brick, and if there is any water in the brick in excess which has not flowed off during the standing, because of air pockets preventing its passage, the juggling of the brick by the mason will free this excess water during the laying, and will result in having the bottom side of the brick 100 per cent wet when laying, which will result in poor bond, as before noted.

From the previous discussion it is evident that the mortar must have sufficient water in excess to allow for water flow and still have sufficient water to permit its own hardening. The mortar must also have sufficient cement, and of such a nature as to have sufficient fine cement particles which may be carried along by water flow. It is my belief that most Portland cements of today have the amount of fine particles which are necessary.

These microphotographs are surface exposures, and thin sections for further study under polarized light, now being prepared, may help in clearing up this amazing and exceedingly interesting problem.

I have not discussed many of the masonry units now in use, but they need study just as much as for clay brick, and probably will be carefully analyzed.

THE POLLUTION AND SELF-PURIFICATION OF THE POCASSET RIVER IN RHODE ISLAND

F. WELLINGTON GILCREAS*

(Presented at the meeting of the Sanitary Section of the Boston Society of Civil Engineers on February 1, 1933)

THE Pocasset River is a small stream located in Rhode Island, and subject at several points in its course to heavy industrial pollution. The stream is too small to have much value for recreational purposes, and is used almost wholly as a means of carrying away industrial wastes. The river is approximately ten miles long, rising in the town of Johnston, and flowing southeasterly through the town of Hughesdale, Thornton and Cranston, all industrial centers, and discharging into the Pawtuxet River just below Pettaconsett.

The total drainage area as computed by the Rhode Island Board of Purification of Waters is about 19.5 square miles. The flow of the river, on which the storage is large, is generally low, varying from 30 to 35 million gallons daily at seasons of flood flow, to less than 5 million gallons daily, and sometimes as low as 2.5 million gallons daily in dry periods of the summer months. The average flow per year might be estimated to be between 12 to 18 million gallons daily. The velocity of the stream is far from rapid, and there are but few stretches of swift water in its course.

According to the 1924 Report of the Rhode Island Board of Purification of Waters, the drainage area in the upper part of the stream is largely farm land, and there is no industrial pollution. However, between Hughesdale and Thornton is located a small textile mill devoted entirely to weaving. This discharges the effluent from mill toilets serving about forty persons.

At Thornton, the Pocasset is joined by Cedar Swamp Brook, its principal tributary, on which are located two textile mills, — one a wool-scouring plant, and the other a weaving and mercerizing mill. The wastes from the wool-scouring plant are treated in a well operated acid-cracking plant for the removal of wool grease, the effluent, containing considerable amounts of putrescible organic matter, being discharged directly into the stream. The wastes from the second mill consist chiefly of spent bleaching and dyeing liquors and domestic sewage.

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* Chemist, Weston & Sampson.

Below Thornton and on the main stream is located the Pocasset Mill for spinning yarn from wool tops. The only waste here is the effluent of cesspools receiving the sewage from toilets serving between 500 and 600 persons.

From this point the river flows about a mile through open country, receiving in its course the flow from two small controlled reservoirs, and finally discharging into a large pond known as the Print Works Pond. This is a large shallow body of water, something over a mile in length, and affording a considerable period of storage. At the outlet of the pond are located the plants of the Cranston Print Works and the Narragansett Finishing Company, which discharge waste from printing, bleaching and finishing processes, together with the sewage of about 500 persons.

Below these mills the river flows through open country for about 2.5 miles, receiving no further pollution but a small amount of diluting water from a small pond which discharges into the river. At the end of this 2.5-mile flow there is a dam creating a small pond. A short distance below this dam the Pocasset discharges into the Pawtuxet River, receiving just above the point of discharge the flow from a small brook carrying the sewage from a boys' school with a population of about 200.

As there is but little pollution in the upper stretches of the river, attention in this study was confined to the Cedar Swamp Brook and points below its confluence with the Pocasset.

Studies by the Rhode Island Board of Purification of Waters, and reported in their 1924 report, indicated that the small amount of sewage discharged into the river between Hughesdale and Thornton was negligible in its effect on the character of the stream.

Cedar Swamp Brook contributes the only considerable amount of pollution from that portion of the river above the Print Works Pond. This pollution consists of the wastes from the grease recovery plant of the woolen mill, which wastes contain considerable putrescible matter, some wool grease, sewage from the mill toilets, and the spent bleaching and dyeing wastes from the second mill on the stream. The addition of this waste causes an abrupt drop in the dissolved oxygen, as shown in Fig. 1, and a corresponding increase in the oxygen consumed, as seen in Fig. 3. No biochemical oxygen demand determinations were made on samples from this part of the river.

The appearance of the stream below these mills is unsatisfactory. Considerable suspended matter is in evidence, although sufficient oxygen was present to prevent any nuisance due to putrefaction. The river banks and bed of the stream are at all times very unsightly, due to deposits of rags and suspended matter in the waste discharged, and scraps of wool, also accumulated piles of automobile tires, baby carriages and similar discarded junk — all adding to the unsightly conditions.

A short distance below this point of pollution, Cedar Swamp Brook joins the main river, which is relatively free from pollution. Flowing through open country, in a leisurely fashion, for about two miles, and being subject to no serious pollution, the river shows the effect of natural purification, the results of previous pollution being gradually removed. The dissolved oxygen increases, due to re-aëration and the diluting effects of the relatively clean water of the main stream, and the oxygen consumed value drops appreciably as the organic matter is oxidized and the suspended matter gradually settles out. The appearance of the stream improves with the removal of the polluting matter. Fish life, while not abundant, is present, and the stream has a satisfactory appearance.

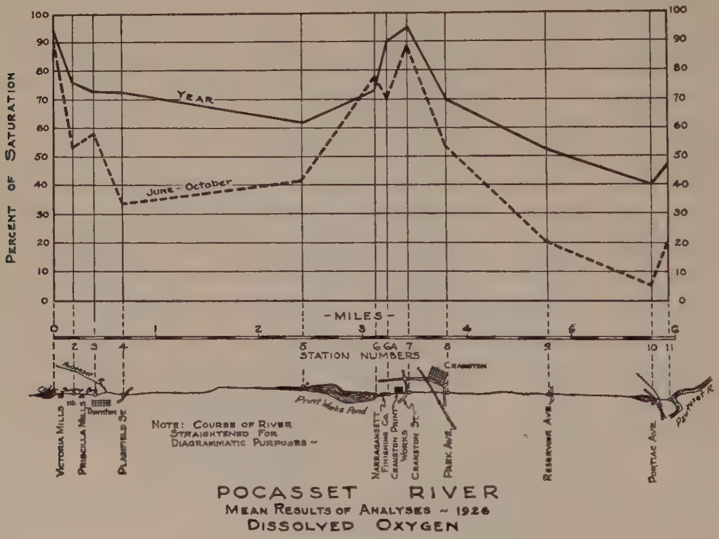


FIG. 1

The Print Works Pond, which affords considerable storage, completes the process of purification. As stated above, this is a large, shallow body of water, well adapted to the processes of self-purification.

While oxygen consumed values change but slightly, the dissolved oxygen values increase abruptly as the water progresses through the pond. Luxurious growths of algæ aid this process of purification during the warm months and contribute largely to the re-aëration shown in the increased dissolved oxygen content. The growth of algæ is an additional proof of the purification which has taken place in the course of Cedar Swamp Brook and the main stream, and is taking place in the pond; also an evidence of the heavy burden of pollution from above.

At the outlet of the pond the river is well aërated, the dissolved oxygen content averaging 80 per cent of saturation, while in the summer months even 100 per cent of saturation, because of algæ growths, is not uncommon. The biochemical oxygen demand is very low, averaging about 5 p. p. m. Just below the outlet of the pond, after the river flows over the spillway of a dam, it receives its heaviest pollution load, — the waste from the Cranston Print Works and the Narragansett Finishing Company.

These two mills, which occupy buildings in the same mill yard, are engaged in the bleaching, printing, mercerizing and finishing of cotton fabrics. During periods of low stream flow, nearly the entire volume of the river is diverted through the mills for use in their manufacturing processes. The wastes from these mills amount to about 1.75 million gallons daily, and are discharged directly into the stream. These wastes consist of spent bleach and dye liquors, wash water, soapy water, starch and kier liquors, with domestic sewage from toilets serving in the neighborhood of 600 persons.

Some of these wastes, of course, such as the wash waters and spent bleach liquor, do not place a very heavy burden upon the stream. The putrescible starchy liquors, together with the alkaline kier liquors of high organic content and the spent dye wastes, place a very heavy load upon the stream. The domestic sewage also contributes its share of the burden. Their effect on the appearance of the stream is most decided.

Just below the mills, the river is most unsightly. The suspended matter is high in amount. The river is filled with floating débris, rags, boxes, etc., while the color of the water may vary through the spectrum, depending upon the sort of work being carried out at the particular moment in the mill, changing very quickly whenever a new batch of dye waste is discharged into the stream.

During the remainder of the 2.5 miles of flow to the small Pontiac Avenue Pond, the appearance of the river is continuously bad, especially in the periods of low flow. The color is black. The suspended matter is always noticeable, although decreasing in amount downstream. The appearance of the water in the pond at Pontiac Avenue, where there is usually considerable floating sludge in evidence, is always bad.

The effect of the waste can best be traced by consideration of the changes in the dissolved oxygen during the flow of the river from its point of pollution to its confluence with the Pawtuxet (Fig. 1). Starting at about 80 per cent saturation at the outlet of the Print Works Pond, a slight increase in dissolved oxygen is noted just below the mills. Probably the discharge of large volumes of spent bleach liquor just above the sampling points accounts for this increase. Progressing downstream, the oxygen drops off gradually as it is absorbed by the putrefactive processes going on, until at the small pond at Pontiac Avenue, just above the confluence with the Pawtuxet River, the oxygen is practically exhausted. During a considerable period in the summer months, when the flow of the river is at a minimum, the oxygen is entirely exhausted and putrefactive conditions exist, with resulting foul odors and accumulation of floating sludge. The escape of gas at this point is common, with the formation of large bubbles at times sufficient to give the appearance of boiling. Hydrogen sulfide is present in large amounts. Naturally this pond represents a very considerable nuisance.

In periods of very low flow, the dissolved oxygen of the stream is exhausted before reaching this pond, creating nuisance conditions at a considerable distance upstream.

At the outlet of this pond, the river falls over a low dam which provides some re-aëration. This, and the small amount of diluting water entering just below the dam, increases the dissolved oxygen content slightly, to a maximum usually of about 20 per cent saturation at the point where the Pocasset discharges into the Pawtuxet River. However, the waters of the Pocasset, due to their dark black color, can be traced for some distance in the cleaner Pawtuxet.

It is, of course, the balance existing between the dissolved oxygen value and the biochemical oxygen demand which determines the character of a stream, and the values for the biochemical oxygen demand are therefore of equal importance with dissolved oxygen. These follow closely the curve of dissolved oxygen in the diagram (Fig. 2), and shed further light on the effect of the wastes on the river. It will be noted that the biochemical oxygen demand, which is very small at the outlet of the Print Works Pond, — about 5 p. p. m., — increases very abruptly below the point of discharge of the mill wastes, — from 5 or less p. p. m. to an average of 75 p. p. m., or even higher.

A short distance downstream there is a further slight increase, probably due to the disappearance of the bleaching liquor and its effect upon the determination, as was noted in connection with the dissolved oxygen results. From that point there is a gradual decrease to a minimum of from 25 to 35 p. p. m. at the Pontiac Avenue Pond. During the 2.5 miles' flow, putrefaction is going on actively, with the resulting exhaustion of the oxygen present in the stream, and the gradual oxidation of the organic matter present, so that as one goes downstream, less and less oxygen is required to prevent anaërobic putrefaction and to restore aërobic fermentation. However, during a large part of the year the demand is way ahead of the supply in lower stretches of the river.

Consideration of the oxygen-consumed values (Fig. 3) support this deduction. The curve follows very closely those showing the dissolved oxygen and biochemical oxygen demand contents. As oxidation proceeds, the organic matter is gradually removed, and the resulting values for oxygen consumed decrease, reaching a minimum of 20 to 30 p. p. m. at the Pontiac Avenue Pond. Of course, were the biochemical oxygen demand at Pontiac Avenue always less than the supply of dissolved oxygen, no nuisance would exist. However, this is seldom the case, especially when the flow of the river is low.

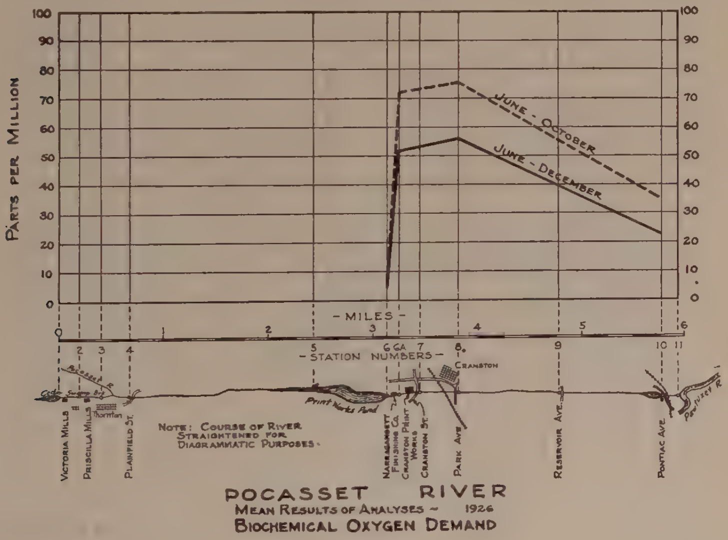
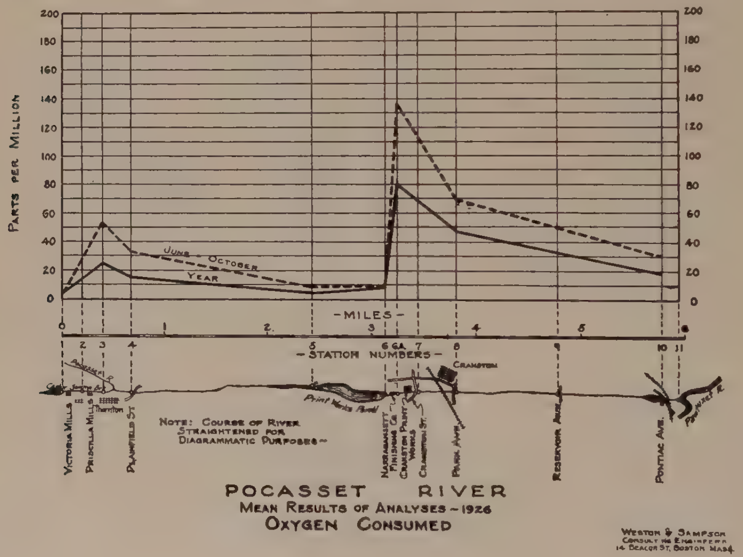


FIG. 2

The effect of these wastes is, of course, much more pronounced during the period of the year from June to October, which is the season of year that flows are at a minimum and temperature conditions are at a maximum. During other seasons of the year, when more water is available, the results are similar but less in degree; therefore less of a nuisance exists. However, the appearance of the river is generally bad, even during periods of relatively high flows. The monthly variations through the year in the dissolved oxygen and the oxygen consumed and other constituents is indicated on the accompanying diagrams. Fig. 4 shows these values just below where the mill discharges and Fig. 5 at the Pontiac Avenue Pond just above the Pawtuxet River. A study of these graphs indicates that river conditions are worst during July, August and September, and are at their best during the winter and spring months. These facts are, of course, in accordance with usual river flows which are lowest in summer and highest in winter and spring.



POCASSET RIVER
MEAN RESULTS OF ANALYSES – 1926
OXYGEN CONSUMED

FIG. 3

In other words, in the seasons when dilution is sufficient, pollution is cared for naturally by the stream, without the creation of a nuisance due to anaërobic conditions. The question is the amount of dilution which is required to prevent a visible nuisance.

In order that a stream may remain in a clean and satisfactory condition, the dissolved oxygen should not be reduced by the demands of added pollution to much less than 50 per cent of saturation. The pollution added to the Pocasset River has exhausted all of the oxygen available and in a short time of transit. Of course, if the volume of diluting water available were larger, the amount of reduction would be correspondingly less.

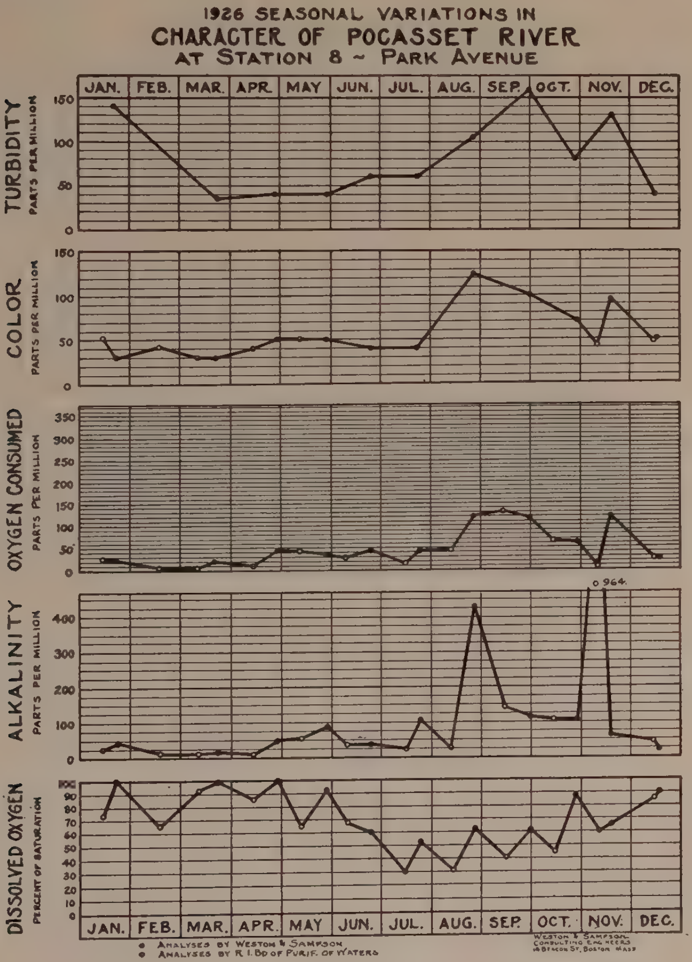


FIG. 4

The combined wastes of the two mills, with the wash water and bleach liquor removed, have a volume of approximately 0.7 million gallons daily, with a biochemical oxygen demand averaging approximately 260 p. p. m., which would be equivalent to a demand of 1,500 pounds of oxygen daily to insure complete stability of the waste. If the river is only 80 per cent saturated with oxygen at a temperature of 25° C., which is a summer average, there would be available in the river at the point of discharge of the wastes only 6.9 p. p. m. of oxygen, or 58 pounds per million gallons, which, for a flow of 5 million gallons daily, an average minimum, would provide only 290 pounds of oxygen daily. Neglecting re-aëration, to provide sufficient oxygen to completely oxidize the added pollution would require a flow at least five times as large, or about 25 million gallons daily.

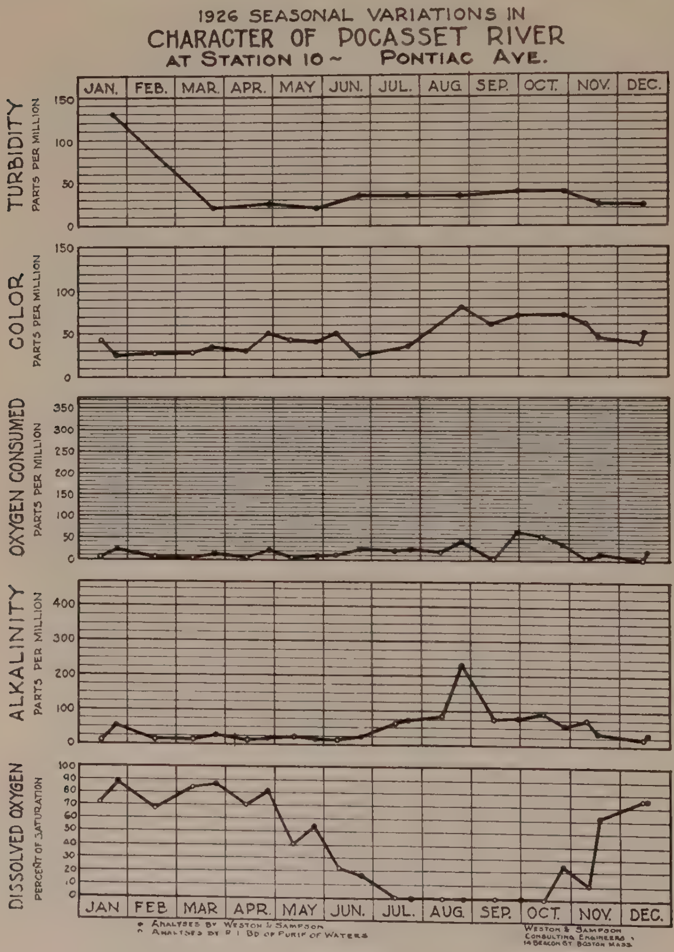


FIG. 5

If the oxygen made available by re-aëration of the stream in its 2.5 miles of flow to Pontiac Avenue is considered, this dilution factor might be reduced materially, possibly to 20 million gallons daily, or considerably more than the average flow. This dilution would provide no excess oxygen to maintain a saturation value of 50 per cent. Flows of this magnitude and greater are available during the winter, spring and late fall, at which times anaërobic conditions do not prevail, sufficient dissolved oxygen being present in the entire course of the river.

Treatment of the wastes to reduce their organic load would also serve to keep the river in a clean condition. Treatment consisting of sedimentation, trickling filters and secondary filtration would reduce the biochemical oxygen demand of the final effluent to a degree where it could be discharged into the stream without causing a material reduction of the dissolved oxygen content, even with the low flow obtaining in dry periods of the summer.

It is interesting to note, regarding the condition of the upper part of the river, — that portion above the Print Works Pond, — that since this study was made, the mills on Cedar Swamp Brook have been closed. The effect on the character of the river has been marked; no reduction in the dissolved oxygen occurred below these mills, and the growth of Lemna in the Print Works Pond were somewhat less in amount. The closing of the Narragansett Finishing Company reduced the volume of waste discharged at that point, resulting in a slightly better condition of the river below. However, the normally increasing volume and character of the waste discharged by the Cranston Print Works still makes the stream unsatisfactory, and anaërobic conditions exist at Pontiac Avenue as before.

SUMMARY.

While the study of the pollution of this particular river did not encounter any unusual conditions, it is of interest in several ways. The upper portion of the river illustrates the results of pollution and recovery therefrom, and particularly the part played by storage in a large and rather shallow pond upon such recovery. Below the pond is an illustration of heavy pollution with particularly putrescible wastes, and the efforts of the river to purify itself and digest this unwelcome pollution as quickly and as thoroughly as possible.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

JANUARY 25, 1933 — A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers Club, and was called to order at 7 P.M. by the President, Ralph W. Horne. About 80 attended.

The President announced the death of the following members: William A. Johnson, died December 20, 1932, a member since May 19, 1920; Gregory P. Connolly, died January 16, 1933, a member since April 21, 1915; Ira W. McConnell, died January 8, 1933, a member since May 15, 1912; Nathan Ginsburg, died Nov. 24, 1932, a member since Sept. 24, 1930; William H. Pitman, died January 22, 1933, a Junior member since November 17, 1926.

The Secretary reported that the following were elected to membership by the Board of Government on January 25, 1933:

Grade of Member: Thomas Henry Sexton, R. Whitney Pierce.

Grade of Junior: Paul Alfred Beigbeder.

Grade of Student: Clarence Banson, William E. Bishop, Louis L. Capone, Harry Albin Carlson, Richard Louis Dunning, Donald B. Evans, Elliot C. Farwell, Frederick Hall, Philip Leahy, William Moberger, Paul C. Swanson, John A. Sweeney.

The President then introduced the speakers of the evening, who gave a symposium on "Protection of Hartford South Meadows."

The speakers were as follows: Roscoe N. Clark, city engineer, Hartford, Conn.; Frederic H. Fay of Fay, Spofford & Thorndike; Prof. Kenneth C. Reynolds, M. I. T.; Prof. Glennon Gilboy, M. I. T.; W. S. Brewer, resident engineer, Hartford, Conn.; William A. D. Wurts, designing engineer, Hartford, Conn.

At Hartford, Conn., the South Meadows, an area of 1,200 acres, located just over a mile from the center of the city, was a low lying tract of land, covered with water when the Connecticut River was at flood stages. Several years ago Brainard Flying Field was located on the northerly or higher portion of this area, and it was decided to protect it from flood waters of the Connecticut by means of a dike. The building of this structure upon a porous, highly water-bearing soil, using materials locally available, involved some unusual engineering problems. Design and construction of this dike and its appurtenant structures were described by the engineers directly responsible for the several portions of the work and illustrated by lantern slides and moving pictures.

The meeting adjourned at 10 P.M.

EVERETT N. HUTCHINS, *Secretary.*

FEBRUARY 15, 1933. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order by Vice-President John B. Babcock, 3d, at 7 P.M.

This meeting was the annual joint meeting with the following student engineering societies: Northeastern University Section of the Boston Society of Civil Engineers, and the Student Chapters of the Harvard Engineering School, Massachusetts Institute of Technology and Tufts College.

About 235 members and guests were present, and 220 attended the buffet supper and smoker preceding it. During the supper, music was furnished by representatives of the musical clubs of Northeastern University.

Mr. Babcock stated that this joint meeting had been an annual event for more than twenty years, and its success is due to the co-operation of the officers of the student organizations and of the faculty members who have maintained the interest of the students in this event.

The speaker of the evening was Mr. George O. Sanford, chief of the Engineering Division of the Washington office of the Bureau of Reclamation, United States Department of the Interior. His talk described the organization of the Bureau of Reclamation, its operations, financial structure and the results achieved. Construction features of the Gibson Dam, Sun River Project, Montana, and recent progress on the work of Hoover Dam on the Colorado River were described. Lantern slides and moving pictures illustrated much of this work.

The meeting adjourned at 9.30 P.M.

EVERETT N. HUTCHINS, *Secretary.*

Sanitary Section

FEBRUARY 1, 1933. — As usual, a supper was enjoyed at Patten's Restaurant, before the meeting.

At 7.15 P.M. the meeting was called to order in the rooms of the Engineering Societies, with 27 members and guests present.

A Nominating Committee was appointed by the Executive Committee, consisting of Francis H. Kingsbury, Chairman, Frank W. Gilcreas and Harrison P. Eddy, Jr.

Mr. Frank W. Gilcreas then presented a paper on "The Pollution and Self-Purification of the Pocasset River in Rhode Island." Among those who took part in the discussion following the paper were Messrs. R. S. Weston, A. L. Fales, F. H. Kingsbury, R. W. Horne, C. I. Stirling, Jr., F. C. Williams, E. S. Chase, A. D. Weston and Prof. G. M. Fair.

FRANK L. FLOOD, *Clerk.*

Designers Section

JANUARY 12, 1932. — The meeting of the Designers Section was called to order by Professor Weaver, Chairman *pro tem,* at 6 P.M. in the Affiliation Rooms.

The minutes of the December meeting were read and approved.

Notice was read calling attention to the show "Kicking In," to be given February 6, 7 and 8 for the benefit of the Emergency Planning Bureau.

Professor Weaver introduced the speakers for the evening. The first speaker was Mr. LeRoy M. Hersum, who gave a paper on "Combined Stresses in Steel Columns." The second speaker was Prof. Robinson Abbott, who gave a paper on "Some Phases of Continuous Beams." The third speaker was W. W. Bigelow, who gave a paper on "A Few Mathematical Stunts." The fourth speaker was Mr. Frederick Crabtree, who gave a paper on "Ways to Lessen Cost in Steel Structures." The fifth speaker was Mr. Abraham Woolf, who gave a paper on "The Resistance of Footings to Uplift."

The papers were followed by a discussion of them. The meeting adjourned at 8.05 P.M.

Forty-five members and guests were present.

E. A. VARNEY, *Clerk pro tem.*

FEBRUARY 8, 1933. — A regular meeting of the Designers Section was held in the rooms of the Engineering Societies of Boston on February 8, 1933. The meeting was called to order at 6.15 by Chairman Ropes. It was voted that the Chairman select three members for the Nominating Committee. Mr. Ropes named the three former chairmen of the Section: Wm. D. Henderson, Chairman, Erwin Harsch and N. P. Randlett.

Mr. Irving Crosby then gave a paper on "The Geological Formations of Greater Boston." In a very interesting and comprehensive talk he outlined the recent geological history of this region, with particular reference to rocks and soils now used as supports for our engineering structures. He also discussed characteristics and relative bearing values of the various soil materials encountered in this vicinity. A short discussion followed.

The meeting adjourned at 7.40. There were 55 members and guests present.

Henry Brask, *Clerk pro tem.*

ADDITIONS

Members

Glennon Gilboy, Massachusetts Institute of Technology, Cambridge, Mass.
R. Whitney Pierce, 60 Commonwealth Road, Watertown, Mass.
Thomas H. Sexton, 33 Wade Street, Brighton, Mass.

Student Members

Warren M. Campbell, 68 Bellingham Avenue, Revere, Mass.
Frederick K. Hall, 247 Kent Street, Brookline, Mass.
Wilfred Pitts, 66 Warrenton Street, Boston, Mass.

DEATHS

Nathan Ginsburg	Nov. 24, 1932
Ira W. McConnell	Jan. 8, 1933
Gregory P. Connolly	Jan. 16, 1933
William H. Pitman	Jan. 22, 1933

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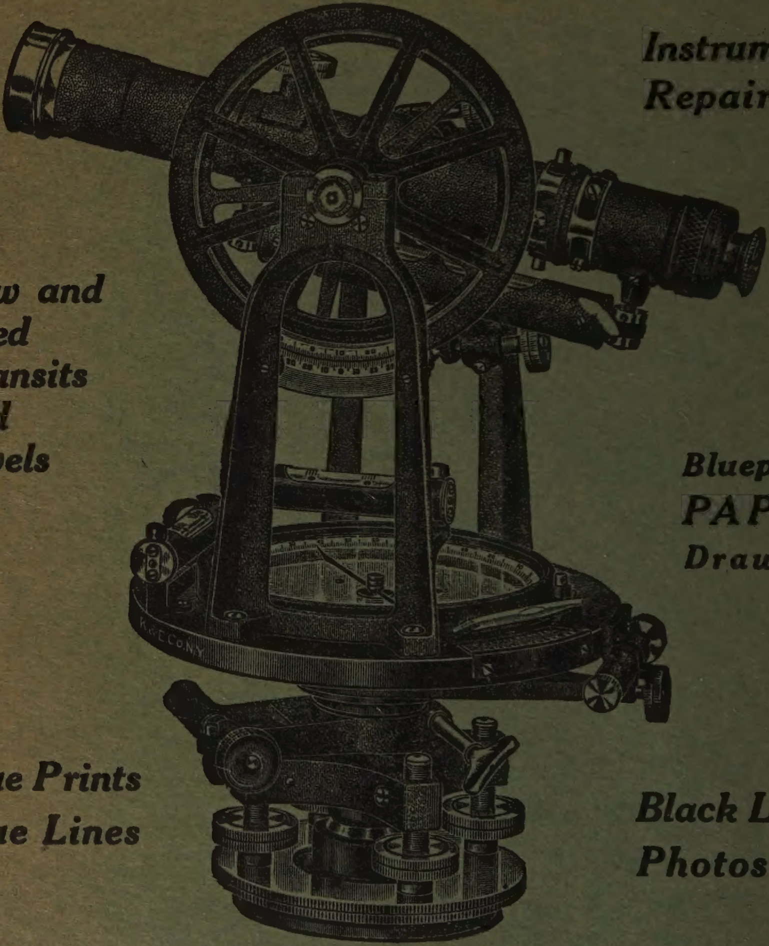

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